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CROP PHENOLOGY AND SEED YIELD AS INFLUENCED BY HIGH TEMPERATURE STRESS IN RICE

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ABSTRACT

High temperature stress is one of the stresses, which adversely affects crop production. Being grown in narrow temperature range, a slight increase in the temperature will drastically reduce the yield of rice. It is important to study the impact of temperature stress, on seed yield attributing characters so as to develop mitigation strategies. Hence, the present investigation was carried out by raising five rice varieties viz., MDU 5, ASD 16, CO 51, Anna (R) 4 and ADT 43 in field condition at Coimbatore under two temperature regimes-high (summer, 2016) and normal (rabi, 2016) temperature in field condition, so as to explore its impact on crop phenology and seed yield. Except for plant height no significant influence of high temperature on vegetative growth of the plants were observed. Increased plant height was observed in case of high temperature conditions. Reduced leaf area and leaf chlorophyll index were also observed. Exposure of plants to high temperature also resulted in early flowering in all the varieties under testing. Total number of spike lets per panicle, number of filled seed per panicle and seed set were significantly lower in plants exposed to high temperature which ultimately resulted in lower seed yield.

KEYWORDS: Rice, Temperature Stress, Seed Set, Yield & Harvest Index

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INTRODUCTION

The world is looking forward to the agriculture sector and considers it as the sole solution to produce adequate food for its ever growing population. High temperature (HT), due to increasing concentration of CO_2 and other atmospheric greenhouse gases, is now considered to be one of the major abiotic stresses for restricting plant growth and productivity, thereby impeding the food production especially the rice production. In India, rice is grown in an area of 43.2 million hectare with a production of 104 million tonnes and productivity of 2.4 tonnes / ha during 2015-16 (Anon., 2017). Any further increases in mean temperatures or of short episodes of high temperatures during sensitive stages may be supra-optimal and reduce grain yield. Rice grain production drops 10% for each 1 °C increase in minimum growing season temperature (Peng *et al.*, 2004). The rise in atmospheric temperature causes detrimental effects on growth, yield, and quality of the rice crop by affecting its phenology, physiology, and yield components. Processes such as photosynthesis, stomata conductance, seed number, seed size and composition of seeds, and enzyme activities in leaves and seeds are influenced by growth temperature (Reddy and Hodges, 2000; Thomas *et al.*, 2003). Studies have shown that photosynthesis and photosynthetic capacity acclimates under elevated growth temperatures (Vu *et al.*, 1997; Bunce, 2000).

Heat stress tolerance in different growth phases in rice is an intricate phenomenon affecting morphological and yield responses. Determination of these responses could make possible strategies for heat

stressed regions to improve yield. In this perspective, this research is an attempt to explicit growth and yield responses of indigenous cultivars. Most previous warming experiments have been conducted with an all-day warming regime, though the known and predicted elevations of the daily minimum temperature are higher than those of the daily maximum temperature. Thus, the evidence from previous warming experiments may not fully represent the actual responses of rice growth to the anticipated warming. At this backdrop, the present investigation was taken up with the objective of assessing the crop phenology under higher and normal temperature in field conditions.

MATERIALS AND METHODS

Genetically pure seeds of rice varieties MDU 5, ASD 16, CO 51, Anna (R) 4 and ADT 43 obtained from the Department of Rice, Tamil Nadu Agricultural University, Coimbatore were used for this study during the experimental period. The field experiment was carried out at Coimbatore during summer, 2016 and during *rabi*, 2016. The average max. air temperature at flowering during summer, 2016 was 37° C and that during *rabi,* 2016 was 32° C.

The field trial was laid out in Randomised Block Design with four replications. The sowing dates were adjusted such that all varieties come to flowering at the same time. The observations recorded on the plants raised under field conditions were plant height, total number of tillers per plant, number of productive tillers per plant, days to flowering, panicle length, total number of spike lets per panicle, total number of filled seeds per panicle, seed set, seed yield per plant and harvest index. The filled seeds in the main tiller of ten randomly selected plants were counted and seed set per cent was calculated based on the following formula

$$\text{Seed set (\%)} = \frac{\text{Number of filled seed}}{\text{Total number of spike lets}} \times 100$$

Harvest index was recorded as the ratio of grain weight to total plant weight.

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{(Grain yield + Straw yield)}} \times 100$$

To measure the leaf area, from each hill, five random leaves were selected and length and width of those leaves were measured and the leaf area was calculated by the following formula (Palaniswamy and Gomez, 1974).

Leaf area (cm^2) = L x B x K (0.75) x n

L = Length, B= Breadth, K= Extinction coefficient (0.75 for rice), n = Number of leaves per plant. Chlorophyll index was observed at maximum tillering stage using chlorophyll meter (Model CCM 200 plus).

RESULTS

A significant variation was observed among the varieties, treatments and their interaction for plant height. At higher temperature, plant height (91.68 cm) was significantly higher than the normal temperature (87.36 cm). Among the varieties, ASD 16 recorded maximum plant height (98.55 cm) across the temperatures followed by Anna (R) 4 (96.58 cm). The total number of tillers at higher and normal temperatures differed significantly for varieties ASD 16 and CO 51 (decreased from 20 to 19). But, there were significant differences for number of productive tillers per hill at normal (20) and higher temperatures (18). Days to flowering was significantly hastened by higher temperature (83 from 88 days) and varietal as well as interactional effects were also significant (Table 1). Significant differences were observed for leaf characters also due to the differences in temperature. A significantly higher leaf area of 191.86 $cm^2$was observed at normal temperature which got reduced to 171.33 cm^2 at higher temperature. Significantly highest leaf area was observed in ASD

16 and lowest leaf area was recorded in MDU 5. Chlorophyll index was also found to be significantly reduced under higher temperature (31.62) when compared to normal temperature (33.16) (Table 2).

Panicle length was significantly influenced by temperature and varietal differences. A significant reduction was observed in panicle length from 25.30 (normal temperature) to 24.18 cm (higher temperature). Among the varieties, significantly highest panicle length was observed in ASD 16 (27.34 cm). Varietal and temperature effects had significant effect on total number of spike lets per panicle as well as number of filled spike lets per panicle. At normal temperature, about 140 of the 146 spike lets were filled which was reduced to 122 out of 142 spike lets. Number of filled seeds per panicle was significantly higher and equal in ASD 16 and Anna (R) 4 (Table 3).

Significant differences were observed in temperature, varieties and interaction for seed set per cent, seed yield per plant and harvest index. Seed set per cent was significantly reduced from 95.95 to 85.89 per cent when the plant was exposed to normal and higher temperature, respectively. Seed set per cent of ADT 43 was significantly lowest compared to all other varieties which were on par with each other. Significantly lowest interactional effect was observed in ADT 43 at higher temperature (80.02 %). At higher temperature regime, seed yield per plant was significantly reduced to 46.07 g from 51.59 g (normal temperature). Significantly highest harvest index was observed at normal temperature (0.34) when compared to higher temperature (0.30). Interactional effects were also found significant in seed yield per plant, seed set per cent and harvest index (Table 4).

DISCUSSIONS

It is evident from the past research works that the seed yield is highly influenced by the temperature of the crop production area. Higher temperature during the critical growth stages influences plant height, chlorophyll content, number of productive tillers and number of spike lets as well as number of filled spike lets which is finally manifested as decreased seed set and seed yield.

The prominent morphological change evident in the plants grown under high temperature was increased plant height when compared to plants grown under normal temperature. The findings of Oh-e et al. (2007) in rice are also in harmony with our results who reported increased plant height and earlier maximum tillering under high temperature. It is confirmed by Lakshmiprasanna Kata (2014) in rice. In the present study, there was no much impact of heat stress on number of tillers, but the number of productive tillers significantly reduced when grown in high temperature regime. In general, there is a positive correlation between change in temperature and photosynthesis. In wheat green leaf area and productive tillers/plant were drastically reduced under high temperature (30/25 °C, day/night) (Djanaguiraman *et al.*, 2010). High temperature (36/30^{0}C) led to an abnormal loss in chlorophyll and accelerated senescence in wheat plants (Harding *et al.* 1990). Lakshmiprasanna Kata (2014) reported that, plants exposed to increased temperature reduced the leaf area and leaf chlorophyll index. High temperature (ambient+5^{0}C) maintained throughout the crop growth period decreased the leaf photosynthetic rate by 14% (Prasad *et al.*, 2006). Hurkman *et al.* (2009) and Oh-e *et al.* (2007) reported a decrease in photosynthesis rate of 16 % and 40–60%, respectively at mid-ripening due to high temperature. The reduction in chlorophyll content was due to inhibition of porphobilinogen deaminase activity and thus, reduction in protochlide content in the seedlings upon exposure to short duration of heat stress (Tewari and Tripathy, 1998). Most of the scientists are of opinion that the chlorophyll content and photosynthetic rates are reduced under temperature stress, but Mohammed and Tarpley (2009) reported that the high temperature did not affect leaf photosynthetic rates in contrast to other studies.

Dry matter (DM) partitioning varies widely under different temperatures and crops. Stresses like water deficit and heat slower down the assimilation process and the mineral uptake during the grain filling period. High temperature hastens physiological maturity in rice, leading to decreased accumulation of photo synthates in the grain, thereby decreasing plant yield (Seddigh and Jolliff, 1984). Baker and Allen (1993) reported a temperature optimum of 26 °C for grain yield of the *indica*-type rice cultivar IR-30. In those experiments, grain yields declined by about 10% per each 1 °C increase in average day–night air temperature beyond 26 °C and reached zero yields at 36 °C. It may be due to the loss of capacity of endosperm to accumulate dry matter as affected by high temperature (Commuri and Jones, 1999). Also, the elongated rice stems retained more photo synthate, than did ears under high night temperature and due to increased respiration under high temperature stress, biomass production declines. The grain weight decrease results from an early loss of sink activity under high temperature during grain filling period. In addition, cereals generally respond to high temperatures through an increase in the rate of kernel growth, which can lead to a decrease in the duration of dry matter accumulation. Ziska *et al.* (1996) observed that night temperature of 29 °C increases susceptibility of rice to sterility with a subsequent reduction in seed-set and grain yield. Kobata and Uemuki (2004) reported that, under high temperature rice grain filling rate increased while grain filling duration was shortened obviously due to insufficient assimilation and the nutrition competition among grains under high air temperature conditions. Certainly, such responses to high air temperature for rice plants were closely correlated with the reduced grain yield.

Grain yield reduction can also be attributed to high temperature effects on pre-anthesis, post-anthesis development and pollination. John Sheeshy *et al.* (2006) recorded that crop responses to temperature (below the high temperatures that cause infertility in rice) are of the order of -0.5 t ha^{-1} $°C^{-1}$ (or about 6% $°C^{-1}$ at the base yield at average mean daily temperature of 26 °C). Maite Martinez Eixarch and Richard Ellis (2015) reported that, spikelet fertility and seed yield per panicle were severely reduced by extreme temperature in the 14-d period before a thesis. The damage was greater the earlier the panicles were stressed within this period. Later exerted panicles compensated only partly for yield loss. High temperature stress resulted in abscission and abortion of flowers, young pods and developing seeds, resulting in lower seed numbers (Tubiello *et al*., 2007).

In brief, the reduction in photosynthesis coupled with the sterility and inefficient pollination followed by decreased dry matter accumulation period results in lower seed set and seed yield.

CONCLUSIONS

From the above results, it can be concluded that high temperature stress negatively influence the crop phenology and interferes mostly with the leaf characters, reducing the photosynthesis rate. High temperature stress during flowering affects the seed filling which in turn will result in lower seed set and seed yield.

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Table 1: Changes in Crop Phenology of Rice under Normal and Higher Temperatures at Coimbatore

Variety (V)	Plant Height (cm)			Total No. of Tillers Hill^{-1}			No. of Productive Tillers Hill^{-1}			Days to Flowering		
	Normal	Higher	Mean	Normal	Higher	Mean	Normal	Higher	Mean	Normal	Higher	Mean
MDU 5	76.63	79.63	**78.13**	22	22	**22**	21	17	**19**	82	79	**81**
ASD 16	96.33	100.76	**98.55**	20	19	**20**	19	17	**18**	89	84	**87**
CO 51	88.32	90.39	**89.35**	20	19	**20**	20	19	**20**	91	84	**88**
Anna(R)4	93.75	99.41	**96.58**	22	22	**22**	21	20	**21**	93	86	**90**
ADT 43	81.79	88.23	**85.01**	22	22	**22**	21	19	**20**	84	82	**83**
Mean	**87.36**	**91.68**	**89.52**	**21**	**21**	**21**	**20**	**18**	**19**	**88**	**83**	**85**
	V	**T**	**VT**	**V**	**T**	**VT**	**V**	**T**	**VT**	**V**	**T**	**VT**
SEd	0.73	0.46	1.04	0.24	0.15	0.34	0.16	0.10	0.23	0.978	0.62	1.38
CD (P = 0.05)	1.50	0.95	2.12	0.49	0.31	0.70	0.34	0.21	0.48	2.01	1.27	NS

Table 2: Changes in Leaf Characters of Rice under Normal and Higher Temperatures at Coimbatore

Variety (V)	Leaf Area/Plant (cm^2)			Chlorophyll Index		
	Normal	Higher	Mean	Normal	Higher	Mean
MDU 5	159.96	138.02	**148.99**	30.04	27.97	**29.01**
ASD 16	230.87	210.68	**220.78**	35.54	34.55	**35.05**
CO 51	170.03	154.41	**162.22**	32.04	30.13	**31.09**
Anna (R)4	215.51	198.05	**206.78**	36.69	35.32	**36.01**
ADT 43	182.93	155.48	**169.21**	31.48	30.11	**30.80**
Mean	**191.86**	**171.33**	**181.59**	**33.16**	**31.62**	**32.39**
	V	**T**	**VT**	**V**	**T**	**VT**
SEd	1.46	0.93	2.07	0.29	0.19	0.42
CD (P = 0.05)	3.01	1.90	4.25	0.61	0.38	NS

Table 3: Changes in Panicle Length, Spikelet Number, Number of Filled Seed and Sterile Spike lets in Rice under Normal and Higher Temperatures at Coimbatore

Variety (V)	Panicle Length (cm)			Total Number of Spike lets Panicle^{-1}			Number of Filled Seeds Panicle^{-1}			Sterile Spike lets Panicle^{-1} (%)		
	Normal	Higher	Mean	Normal	Higher	Mean	Normal	Higher	Mean	Normal	Higher	Mean
MDU 5	23.75	22.35	**23.05**	139	135	137	133	117	125	4 (11.54)	10 (18.44)	7 (15.34)
ASD 16	27.94	26.74	**27.34**	157	153	155	150	133	142	3 (9.97)	10 (18.44)	7 (15.34)
CO 51	23.76	22.50	**23.13**	157	154	156	151	132	142	3 (9.97)	10 (18.44)	7 (15.34)

Table 3: Contd.,												
Anna (R)4	25.92	25.00	**25.46**	151	147	149	145	132	139	4 (11.54)	7 (15.34)	5 (12.92)
ADT 43	25.15	24.30	**24.73**	124	120	122	119	96	108	4 (11.54)	17 (24.35)	10 (18.44)
Mean	**25.30**	**24.18**	**24.74**	146	142	144	140	122	131	4 (11.54)	11 (19.37)	7 (15.34)
	V	**T**	**VT**	**V**	**T**	**VT**	**V**	**T**	**VT**	**V**	**T**	**VT**
SEd	0.23	0.14	0.32	1.28	0.812	1.82	1.59	1.00	2.25	0.09	0.06	0.13
CD (P = 0.05)	0.47	0.29	NS	2.63	1.67	NS	3.23	2.06	4.61	0.19	0.12	0.26

(Figures in parenthesis indicates transformed arc sine values)

Table 4: Effect of Temperature on Seed set per cent, Seed Yield per Plant (g) and Harvest Index of Rice at Coimbatore

Variety (V)	Seed set per cent			Seed Yield per Plant (g)			Harvest Index		
	Normal	Higher	Mean	Normal	Higher	Mean	Normal	Higher	Mean
MDU 5	95.70	86.66	91.18	49.50	45.10	47.30	0.32	0.28	0.30
ASD 16	95.54	87.12	91.33	50.68	45.65	48.17	0.34	0.30	0.32
CO 51	96.33	85.86	91.10	55.82	49.35	52.59	0.37	0.33	0.35
Anna (R)4	96.03	89.80	92.91	48.64	44.94	46.79	0.31	0.28	0.30
ADT 43	96.16	80.02	88.09	53.29	45.30	49.30	0.36	0.31	0.34
Mean	95.95	85.89	90.92	51.59	46.07	48.83	0.34	0.30	0.32
	V	**T**	**VT**	**V**	**T**	**VT**	**V**	**T**	**VT**
SEd	1.03	0.65	1.46	0.55	0.35	0.78	0.003	0.002	0.004
CD (P = 0.05)	2.12	1.34	2.99	1.13	0.71	1.59	0.005	0.003	0.007